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CONNECTION ASSESSMENT & APPROVAL PROCESS

SYSTEM IMPACT ASSESSMENT REPORT: 1st Addendum

For the Proposed Installation of:

Series Capacitors in the 500kV Circuits X503E & X504E at Nobel TS
SVCs at Porcupine TS & Kirkland Lake TS

Review of the effect on the transfer capability across the Flow-South Interface of not using generation rejection in response to first contingencies

Applicant: Hydro One Networks Inc.

CAA ID Nos.	***2004-160***	*Series Capacitors at Nobel TS*
	2006-223	*SVCs at Porcupine TS & Kirkland Lake TS*

Transmission Assessments & Performance Department

FINAL Version

Date: 15th August 2007

System Impact Assessment Report: 1st Addendum

For the Installation of:
Series Capacitors in the 500kV Hanmer TS to Essa TS circuits, and
Static VAr Compensators at Porcupine TS and Kirkland Lake TS

Review of the effect on the transfer capability across the Flow-South Interface of not using generation rejection in response to first contingencies

Acknowledgement

The IESO wishes to acknowledge the assistance of Hydro One in completing this assessment.

Disclaimers

IESO

This report has been prepared solely for the purpose of assessing whether the connection applicant's proposed connection with the IESO-controlled grid would have an adverse impact on the reliability of the integrated power system and whether the IESO should issue a notice of approval or disapproval of the proposed connection under Chapter 4, section 6 of the Market Rules.

Approval of the proposed connection is based on information provided to the IESO by the Hydro One Networks Inc. at the time the assessment was carried out. The IESO assumes no responsibility for the accuracy or completeness of such information, including the results of studies carried out by the transmitter at the request of the IESO. Furthermore, the connection approval is subject to further consideration due to changes to this information, or to additional information that may become available after the approval has been granted. Approval of the proposed connection means that there are no significant reliability issues or concerns that would prevent connection of the proposed facility to the IESO-controlled grid. However, connection approval does not ensure that a project will meet all connection requirements. In addition, further issues or concerns may be identified by the transmitter during the detailed design phase that may require changes to equipment characteristics and/or configuration to ensure compliance with physical or equipment limitations, or with the Transmission System Code, before connection can be made.

This report has not been prepared for any other purpose and should not be used or relied upon by any person for another purpose. This report has been prepared solely for use by the connection applicant and the IESO in accordance with Chapter 4, section 6 of the Market Rules. The IESO assumes no responsibility to any third party for any use, which it makes of this report. Any liability which the IESO may have to the connection applicant in respect of this report is governed by Chapter 1, section 13 of the Market Rules. In the event that the IESO provides a draft of this report to the connection applicant, you must be aware that the IESO may revise drafts of this report at any time in its sole discretion without notice to you. Although the IESO will use its best efforts to advise you of any such changes, it is the responsibility of the connection applicant to ensure that the most recent version of this report is being used.

Hydro One

Special Notes and Limitations of Study Results

The results reported in this system impact assessment are based on the information available to Hydro One, at the time of the study, suitable for a system impact assessment of a new transmission facility.

HYDRO ONE NETWORKS Inc.

SYSTEM IMPACT ASSESSMENT REPORT:

For the Installation of:

Series Compensation in the 500kV Hanmer TS to Essa TS Circuits, and

Static VAr Compensators at Porcupine TS and Kirkland Lake TS

1st Addendum:

Review of the effect on the transfer capability across the Flow-South Interface of not using generation rejection in response to first contingencies

Summary

The results from the analysis that was performed for this Addendum have been combined with those summarised in the original SIA Report and presented in the following Table.

This Table shows that without using automatic post-contingency generation rejection in response to contingencies involving either of the 500kV Hanmer-to-Essa circuits, the maximum transfer that could be supported across the Flow-South Interface would be restricted to **2110MW.**

This would represent a reduction of approximately *390MW* from the **2500MW** transfer that could be accommodated if generation rejection were to be employed.

The Table also shows that the incremental effect on the transfer capability across the Flow-South Interface of the proposed additions to the transmission facilities in the north-east would be as follows:

	Proposed New facilities	*Transfer Capability across the Flow-South Interface*	
		Incremental Increase	*Cumulative Increase*
1.	Installation of series capacitors at Nobel SS in the 500kV circuits X503E & X504E to provide 50% compensation	340MW	-
2.	Installation of SVCs at Porcupine TS & Kirkland Lake TS	160MW	*500MW*
3.	Installation of additional shunt capacitor banks at Porcupine TS, Hanmer TS & Essa TS	250MW	*750MW*
4.	Installation of an SVC at Mississagi TS, and shunt capacitor banks at Mississagi TS & Algoma TS	60MW	*810MW*

Summary of the maximum transfers that could be supported across the Flow-South Interface					
With all elements in-service pre-contingency *Critical Contingency:* Loss of one of the 500kV circuits between Hanmer TS & Essa TS					
	Reinforcement Scenario		***Transfer Across the Flow-South Interface***		
			With no G/R	***With G/R***	***Amount of G/R***
•	Existing Transmission Facilities		1300MW	1400MW	100MW
•	With the addition of series capacitors at Nobel SS for 50% compensation		1640MW		
		Increase	*340MW*		
•	With the addition of 50% series capacitors at Nobel SS *plus* SVCs at Porcupine TS & Kirkland Lake TS	*Facilities proposed by Hydro One for installation on the North-South corridor*	1800MW	2150MW	505MW
		Increase	*160MW*	*750MW*	
•	With the addition of series capacitors at Nobel SS for 50% compensation *plus* SVCs at Porcupine TS & Kirkland Lake TS *plus* Shunt capacitor banks at Hanmer TS, Porcupine TS & Essa TS		2050MW		
		Increase	*250MW*		
•	With the addition of series capacitors at Nobel SS for 50% compensation *plus* SVCs at Porcupine TS & Kirkland Lake TS *plus* Shunt capacitor banks at Hanmer TS, Porcupine TS & Essa TS *plus* SVC at Mississagi TS and shunt capacitor banks at Mississagi TS & Algoma TS		2110MW	2500MW	560MW
		Increase	*60MW*	*450MW*	

1. Introduction

The original SIA Report had concluded that with the installation of the following facilities on the North-South corridor, as proposed by Hydro One, it would be possible to increase the maximum transfers that could be supported across the Flow-South Interface to **2150MW**:

- Series capacitors in each of the 500kV circuits X503E & X504E, to provide a 50% level of compensation. The series capacitors are to be located at Nobel TS, which is the approximate mid-point of these circuits.
- A Static VAr Compensator (SVC) at Porcupine TS, rated at +300/-100MVAr and connected to the 230kV busbar via a dedicated step-up transformer.
- A further SVC at Kirkland Lake TS, rated at +200/-100MVAr and connected to the 115kV busbar via a dedicated step-up transformer.

To achieve pre-contingency transfers of this level, it was assumed that generation rejection would continue to be used, albeit on an interim basis until major new transmission reinforcement could be installed. For a pre-contingency transfer of 2150MW, the analysis had shown that approximately 500MW of generating capacity would need to be rejected immediately post-contingency.

With the maximum transfer that could be accommodated across the Flow-South Interface increased to 2150MW, it would be possible to incorporate the additional 430MW of new generating capacity proposed under the expansion of the Mattagami River plants. However, with all the existing and committed generating facilities north of Sudbury in-service and operating at their maximum output, it would be necessary to restrict the simultaneous transfers across the Flow-into-Sudbury Interface to approximately 600MW.

The analysis had also shown that a further increase to **2500MW** in the maximum transfer that could be accommodated across the Flow-South Interface could be achieved through the installation of the following facilities on both the North-South corridor and on the Mississagi-to-Sudbury corridor:

•	Porcupine TS	2 x 125MVAr shunt capacitor banks	
•	Hanmer TS	a 2nd 149MVAr shunt capacitor bank	} rated at 220kV
•	Essa TS	a 2nd 182MVAr shunt capacitor bank	
•	Mississagi TS	an SVC rated at +300/-100MVAr	
•	Mississagi TS	a 96MVAr shunt capacitor bank	} rated at 220kV
•	Algoma TS	a 2nd 75MVAr shunt capacitor bank	

For a pre-contingency transfer of 2500MW, approximately 560MW of generating capacity would need to be rejected immediately post-contingency.

With the maximum transfer across the Flow-South Interface increased to 2500MW, this would be sufficient to allow simultaneous transfers across the Flow-into-Sudbury Interface (from the west) of approximately 1000MW to be accommodated. This would allow unrestricted operation of all of the existing and committed generating facilities between Wawa TS and Sudbury, as well as allowing maximum transfers of 325MW eastwards across the East-West Ties.

The transfer capabilities that had been determined in the original SIA Report have been summarised in Table 1.

Transfer Capabilities with no generation rejection

This Addendum identifies that maximum transfers that it would be possible to support across the Flow-South Interface without resorting to the use of generation rejection.

TABLE 1	***From the Original SIA Report: Summary of the maximum transfers that could be supported across the Flow-South Interface***		
With all elements in-service pre-contingency *Critical Contingency:* Loss of one of the 500kV circuits between Hanmer TS & Essa TS			
	Reinforcement Scenario	***Maximum Transfers Across the Flow-South Interface***	
		With no G/R	***With G/R***	***Amount of G/R***
•	Existing Transmission Facilities	*1300MW*	*1400MW*	*100MW*
•	**Facilities proposed by Hydro One for installation on the North-South corridor:** The addition of series capacitors providing 50% compensation at Nobel SS *plus* The installation of SVCs at Porcupine TS & Kirkland Lake TS	-	*2150MW*	*505MW*
	Increase		*750MW*	
•	The addition of series capacitors providing 50% compensation at Nobel SS *plus* The installation of SVCs at Porcupine TS & Kirkland Lake TS *plus* The installation of shunt capacitor banks at Hanmer TS, Porcupine TS & Essa TS *plus* The installation of an SVC at Mississagi TS & shunt capacitors at Mississagi TS & Algoma TS	-	*2500MW*	*560MW*
	Increase		*350MW*	

2. Operational Interfaces

The principal Interfaces that govern the operation of the IESO-controlled Grid within the area under review are as follows:

i. Flow-South/Flow-North Interface -

Representing the combined flow on the 230kV circuit D5H, measured at Otto Holden GS, and on the 500kV circuits X503E & X504E, measured at Essa TS.

ii. East-West Transfer Interface -

Representing the combined flow on the 230kV circuits W21M & W22M, measured at Wawa TS

iii. Mississagi Flow-East Interface -

Representing the combined flow on the 230kV circuits A23P, A24P & X74P, measured at Mississagi TS.

An additional, arbitrary Interface had also been adopted in the original SIA to measure the combined flow into Sudbury from the west. This Interface had been designated the *Flow-East into Sudbury Interface* and it represents the combined flow on the following circuits:

iv. Flow-East into Sudbury - *(Measured at both Hanmer TS and Martindale TS)*

Representing the combined flow on the 230kV circuits X74P & X27A, measured at Hanmer TS, and S22A, measured at Martindale TS.

3. Transient Stability Analysis for a Contingency involving either of the 500kV Hanmer-to-Essa circuits

All of the analysis was performed for a normally-cleared three-phase fault applied at the Hanmer terminal of circuit X503E (or X504E).

The fault was applied after 0.2 seconds and cleared at the Hanmer terminal of the 500kV circuit after a further 66msec.

Clearance of the fault at the remote terminal at Essa TS was assumed to occur after a further 25msec. The total elapsed time from the occurrence of the fault, to the line being removed from service, would therefore be 91msec.

Flow-into-Sudbury

For this analysis, the Flow-into-Sudbury was maintained at approximately 750MW for the cases without the additional SVC at Mississagi TS. This would be equivalent to a transfer across the Mississagi Flow-East Interface of approximately 765MW.

After applying a margin of 10%, this transfer would remain within the voltage-stability limit for transfers across the Mississagi Flow-East Interface once additional facilities have been added to the North-South corridor that would provide crucial voltage support at Hanmer TS.

For the case with the additional SVC assumed to be installed at Mississagi TS, the Flow-into-Sudbury was increased by a nominal 50MW to 823MW.

In the transient stability studies for each of the development scenarios considered, the Flow-South into Sudbury was increased by dispatching additional generating capacity at the Moose River plants until instability of the generating units north of Sudbury occurred.

Provision of a 10% Margin on the Limiting Transfers

The IESO's Transmission Assessment Criteria require that -

'all stability limits should be shown to be stable if the most critical parameter is increased by 10%'.

The limiting transfer beyond which the units were shown to be unstable was therefore reduced by 10% to obtain the maximum transfer capability across the Flow-South Interface for the particular development scenario under review.

3.1 With series capacitors installed at Nobel SS in the 500kV circuits X503E & X504E

Diagrams 1 & 2 shows the results from the last transient stability study for which the generating units remained stable.

In Diagram 2, while the minimum voltage at Porcupine TS is shown to decline to a value that is only marginally above the 70% of nominal voltage that is permitted under the IESO's Ontario Resource & Transmission Assessment Criteria, the voltage is also shown to remain below the 80% of nominal voltage threshold for 525msec. This would be well in excess of the 250msec permitted under the IESO's criteria.

The study was therefore repeated with reduced transfers into Sudbury until the 250msec criterion was satisfied. Diagram 3 shows the voltage responses at the monitored busbars for a transfer of 1270MW into Sudbury (Hanmer) via the 500kV circuit P502X. This would correspond to a transfer of 1807MW across the Flow-South Interface. At this transfer level, the voltage at Porcupine TS is shown to remain below the 80% of nominal voltage threshold for 210msec, which would satisfy the criterion.

After applying a margin of 10%, the effective transient-stability limit for transfers across the Flow-South Interface, with only the new series capacitors at Nobel SS in place and without employing post-contingency generation rejection, would therefore be **1642MW**.

This would represent an increase of approximately *340MW* over the present limit of 1300MW for the condition with no generation rejection initiated post-contingency.

3.2 With series capacitors installed at Nobel SS and SVCs at Porcupine TS & Kirkland Lake TS

The results for the last transient stability study for which the generating units remained stable with the additional SVCs assumed at Porcupine TS and Kirkland Lake TS are summarised in Diagrams 4 & 5.

In Diagram 5, the minimum transient voltage recorded at Porcupine is shown to remain above approximately 77% of the nominal voltage, and would therefore meet the IESO's criteria. However, since the voltage is shown to remain below the 80% threshold for 270msec it would therefore exceed the permitted time of 250msec.

It is worth noting that during this interval, the corresponding reactive power output from the SVC at Porcupine TS is shown to decline. This occurs because the SVC has already reached its maximum rating and it is then unable to control the voltage at the Porcupine 230kV busbar. Under these operating conditions its output then becomes voltage-dependent.

The marginal violation in the time that the voltage remains below the 80% threshold could therefore be addressed either through the provision of a short-term overload capability for the SVC or through a very small reduction (<10MW) in the Flow-South transfer.

After applying the required margin of 10%, the addition of the SVCs at Porcupine TS and Kirkland Lake TS would therefore increase the transient-stability limit for transfers across the Flow-South Interface to **1800MW.**
The installation of the SVCs at Porcupine TS and Kirkland Lake TS would therefore achieve a further increase of approximately *160MW* in the transfer limit over that provided through the installation of the series capacitors at Nobel SS, for the condition with no generation rejection initiated post-contingency.

3.3 With series capacitors installed at Nobel SS; SVCs installed at Porcupine TS & Kirkland Lake TS; and additional shunt capacitor banks installed at Porcupine TS, Hanmer TS & Essa TS

The analysis in the original SIA Report had shown that one of the consequences of increasing the power transfers across the North-South corridor would be a significant increase in the reactive power losses. The installation of additional shunt capacitor banks at Porcupine TS, Hanmer TS and Essa TS was therefore proposed to achieve an improvement in the voltage profile over the North-South corridor.

The results from the transient-stability study for a contingency involving one of the Hanmer-to-Essa 500kV circuits with these additional shunt capacitor banks in-service are shown in Diagrams 6 & 7.

While the response shown in Diagram 7 for the SVC at Porcupine is similar to that shown in Diagram 5, the voltage recorded at Porcupine TS only remains below the 80% threshold for 185msec and would therefore satisfy the IESO's criterion.

The addition of the shunt capacitor banks at Porcupine TS, Hanmer TS and Essa TS would therefore increase the transient-stability limit for transfers across the Flow-South Interface to **2053MW.**

This would represent a further increase of approximately *250MW* in the transfer limit over that which would be provided through the installation of the series capacitors at Nobel SS and the SVCs at Porcupine TS and Kirkland Lake TS, for the condition with no generation rejection initiated post-contingency.

3.4 With series capacitors installed at Nobel SS; SVCs installed at Porcupine TS & Kirkland Lake TS; additional shunt capacitor banks installed at Porcupine TS, Hanmer TS & Essa TS; and an SVC at Mississagi TS and shunt capacitors at Mississagi TS & Algoma TS

In the original SIA Report it had been identified that the transfer into the Sudbury area from the west would need to be restricted to approximately 890MW to avoid instability of the generating units west of Algoma in response to a contingency involving the 500kV circuit P502X, between Hanmer TS and Porcupine TS.

Analysis had shown that the installation of an SVC at Mississagi TS together with shunt capacitor banks at Mississagi TS and Algoma TS would permit higher transfers into Sudbury while maintaining stability in the event of a P502X contingency.

Diagrams 8 & 9 show the results from the transient-stability study for a contingency involving one of the Hanmer-to-Essa 500kV circuits with the additional SVC at Mississagi TS together with the shunt capacitor banks at Mississagi TS and Algoma TS in-service.

In Diagram 9, the behaviour of the SVC at Porcupine TS stays essentially unchanged, with the result that the voltage at Porcupine TS is shown to remain below the 80% threshold for 260msec. As before, this marginal violation could be addressed either through the provision of a short-term overload capability for the SVC or through a minor reduction in the Flow-South transfer.

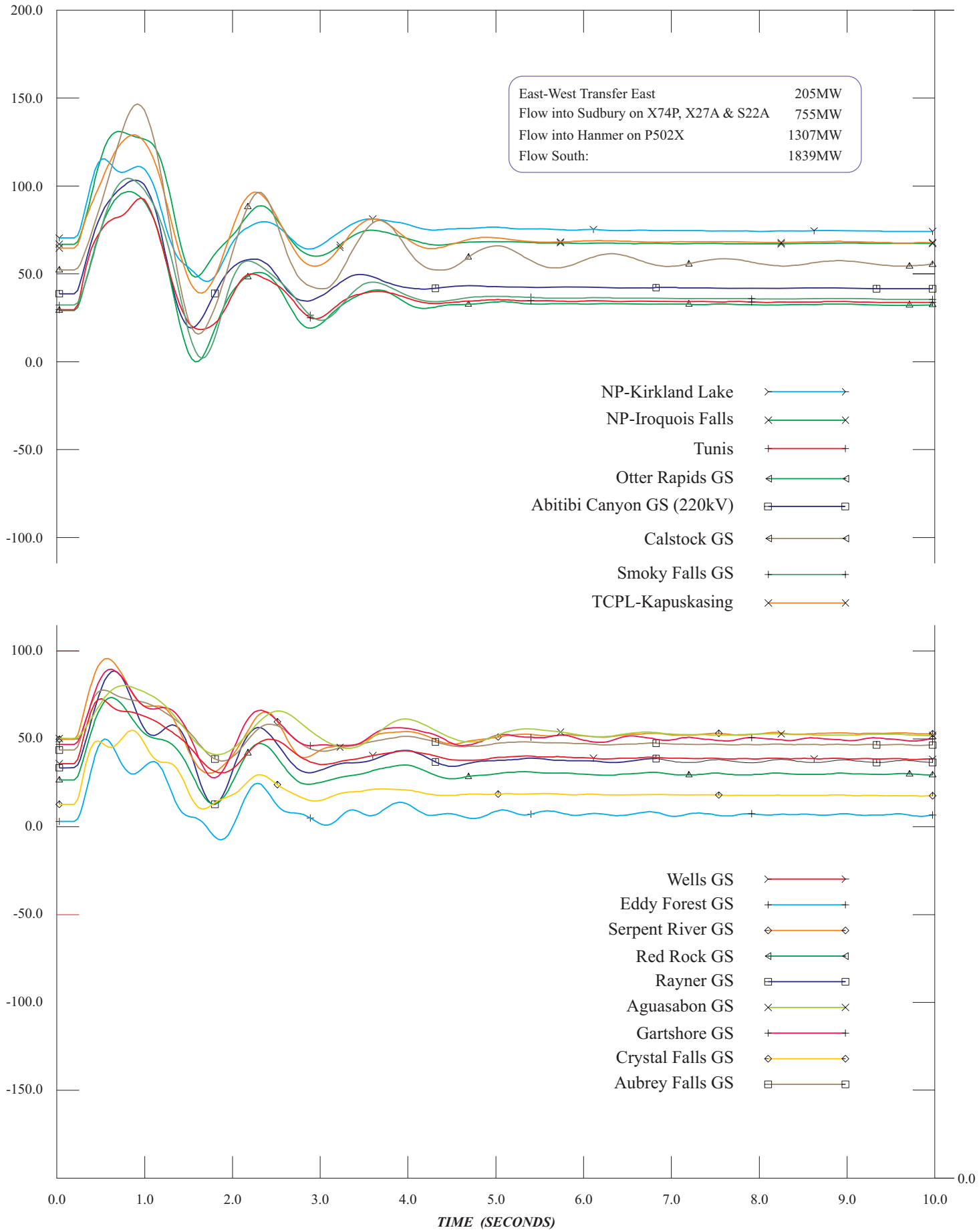
The addition of the SVC at Mississagi TS, together with the shunt capacitor banks at Mississagi TS and Algoma TS would therefore increase the transient-stability limit for transfers across the Flow-South Interface to **2110MW**, after applying the required margin of 10%**.**

This would represent a further increase of approximately *60MW* in the transfer limit over that which would be provided through the installation of the series capacitors at Nobel SS; the SVCs at Porcupine TS and Kirkland Lake TS; and the additional shunt capacitor banks at Porcupine TS, Hanmer TS and Essa TS, for the condition with no generation rejection initiated post-contingency.

3.5 Summary of the transfer capabilities across the Flow-South Interface

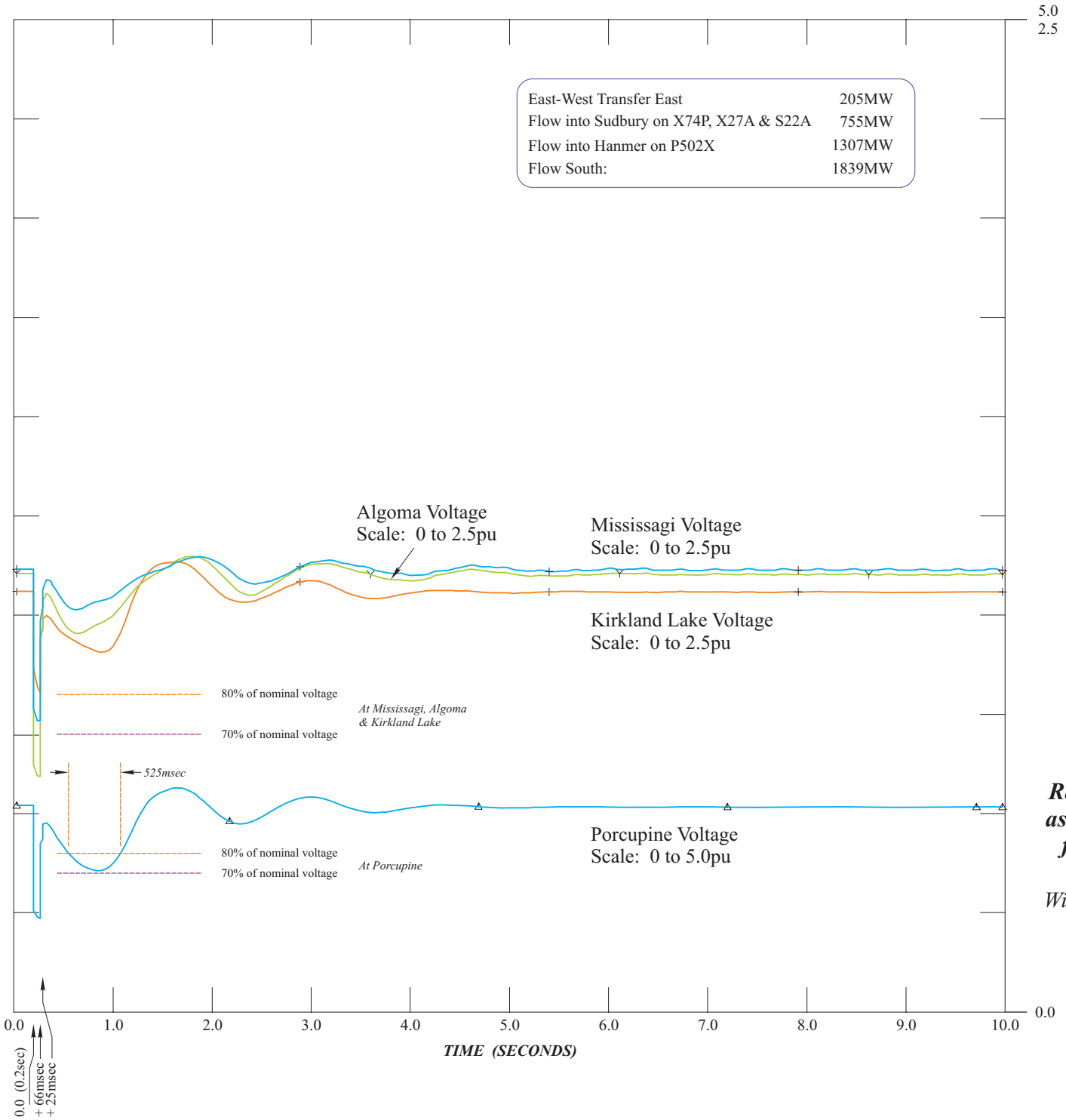
The following Table summarises the transfer capabilities that were presented in the original SIA Report together with the results obtained from the analysis performed for this Addendum.

TABLE 2	***Summary of the maximum transfers that could be supported across the Flow-South Interface***			
With all elements in-service pre-contingency *Critical Contingency:* Loss of one of the 500kV circuits between Hanmer TS & Essa TS				
	Reinforcement Scenario	***Transfer Across the Flow-South Interface***		
		With no G/R	***With G/R***	***Amount of G/R***
•	Existing Transmission Facilities	1300MW	1400MW	100MW
•	With the addition of series capacitors at Nobel SS for 50% compensation	1640MW		
	Increase	*340MW*		
•	With the addition of 50% series capacitors at Nobel SS *plus* SVCs at Porcupine TS & Kirkland Lake TS *Facilities proposed by Hydro One for installation on the North-South corridor*	1800MW	2150MW	505MW
	Increase	*160MW*	*750MW*	
•	With the addition of series capacitors at Nobel SS for 50% compensation *plus* SVCs at Porcupine TS & Kirkland Lake TS *plus* Shunt capacitor banks at Hanmer TS, Porcupine TS & Essa TS	2050MW		
	Increase	*250MW*		
•	With the addition of series capacitors at Nobel SS for 50% compensation *plus* SVCs at Porcupine TS & Kirkland Lake TS *plus* Shunt capacitor banks at Hanmer TS, Porcupine TS & Essa TS *plus* SVC at Mississagi TS and shunt capacitor banks at Mississagi TS & Algoma TS	2110MW	2500MW	560MW
	Increase	*60MW*	*450MW*	



Generator Rotor Angle Responses to a 3-Phase fault on circuit X503E at Hanmer TS
With 50% compensation on the two Hanmer x Essa 500kV circuits

DIAGRAM 1
9th August 2007



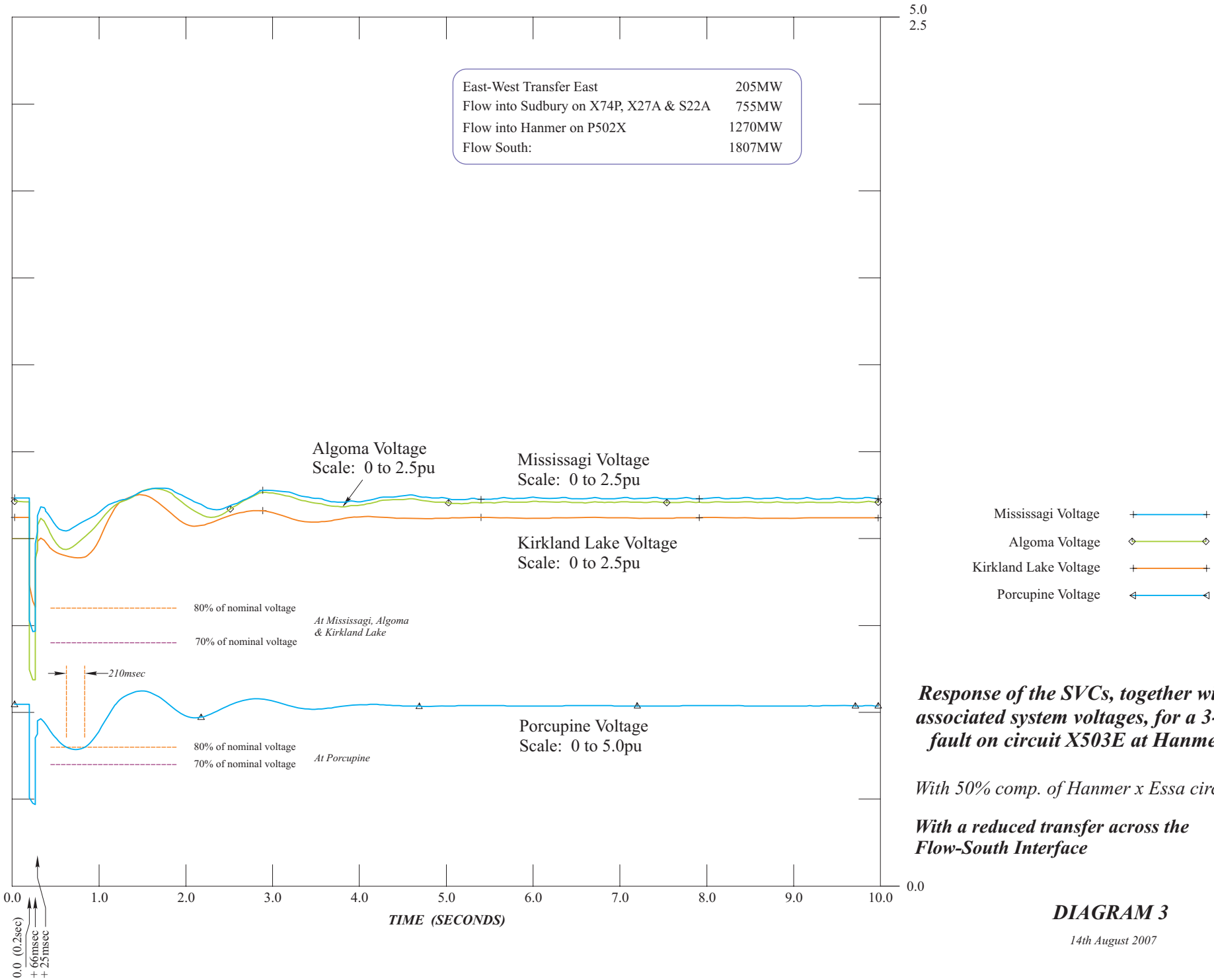
Mississagi Voltage
Algoma Voltage
Kirkland Lake Voltage
Porcupine Voltage

Response of the SVCs, together with the associated system voltages, for a 3-phase fault on circuit X503E at Hanmer TS

With 50% comp. of Hanmer x Essa circuits

DIAGRAM 2

9th August 2007



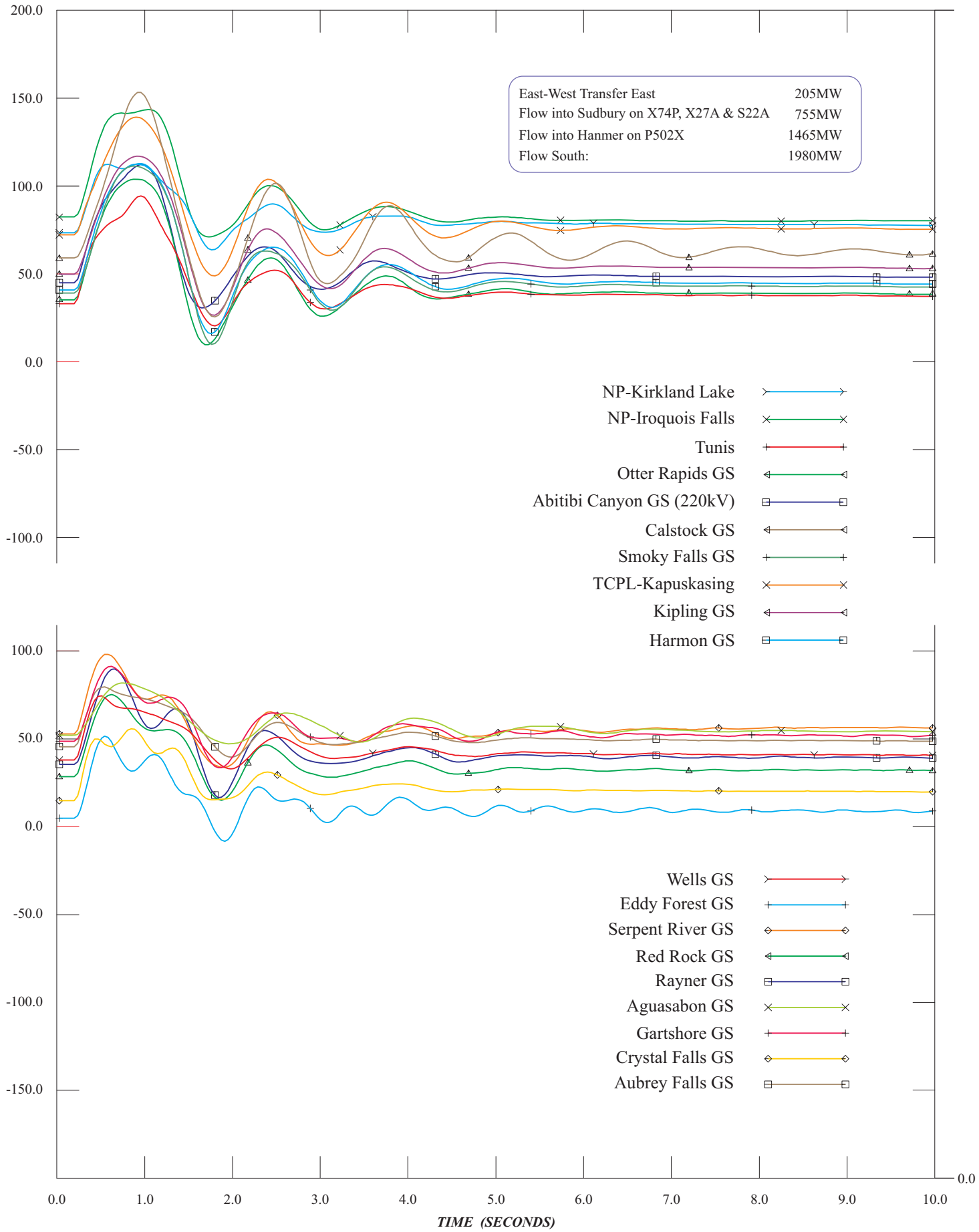
Response of the SVCs, together with the associated system voltages, for a 3-phase fault on circuit X503E at Hanmer TS

With 50% comp. of Hanmer x Essa circuits

With a reduced transfer across the Flow-South Interface

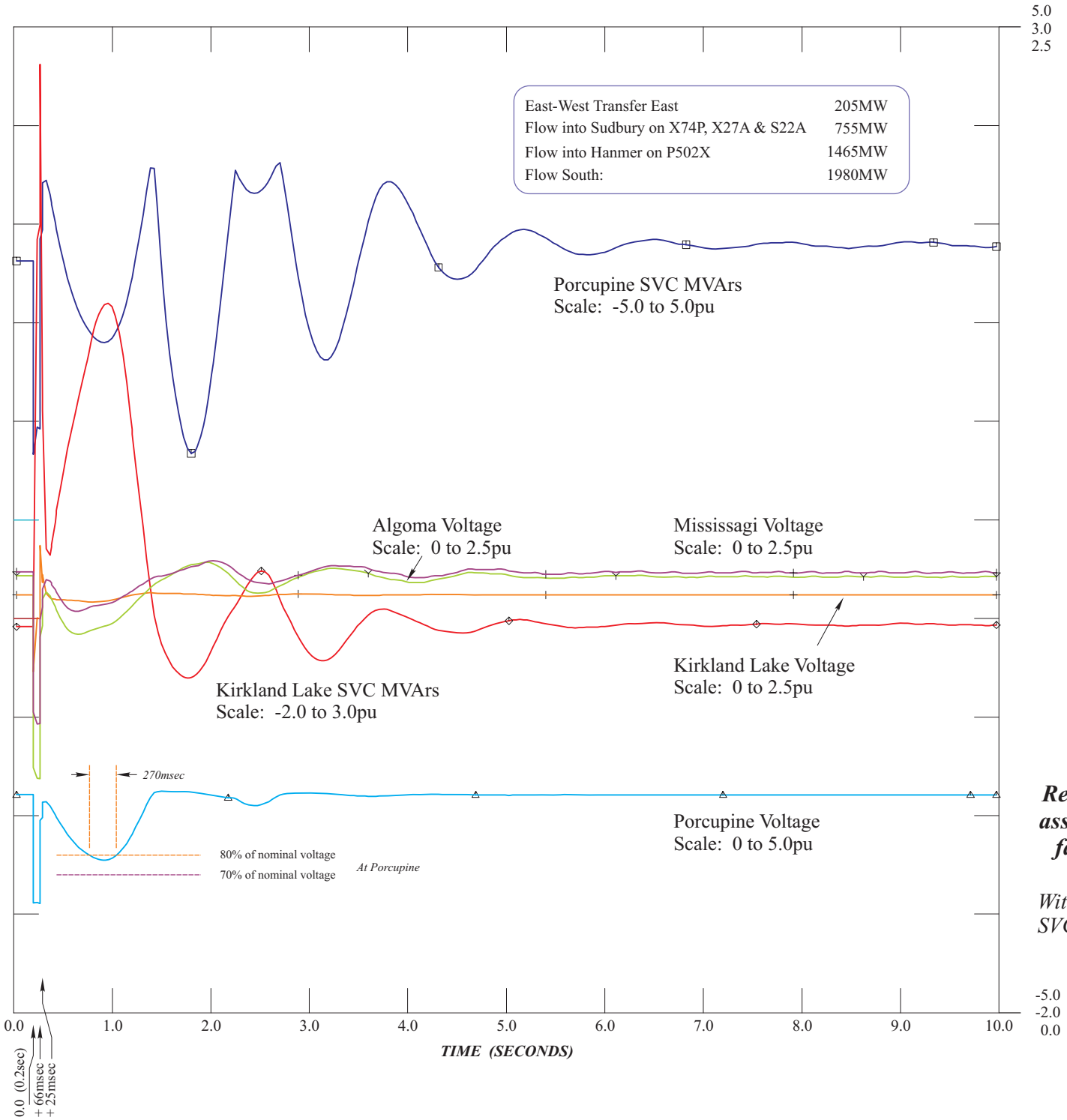
DIAGRAM 3

14th August 2007



Generator Rotor Angle Responses to a 3-Phase fault on circuit X503E at Hanmer TS
With 50% compensation of Hanmer x Essa circuits + SVCs at Porcupine & Kirkland Lake

DIAGRAM 4
9th August 2007



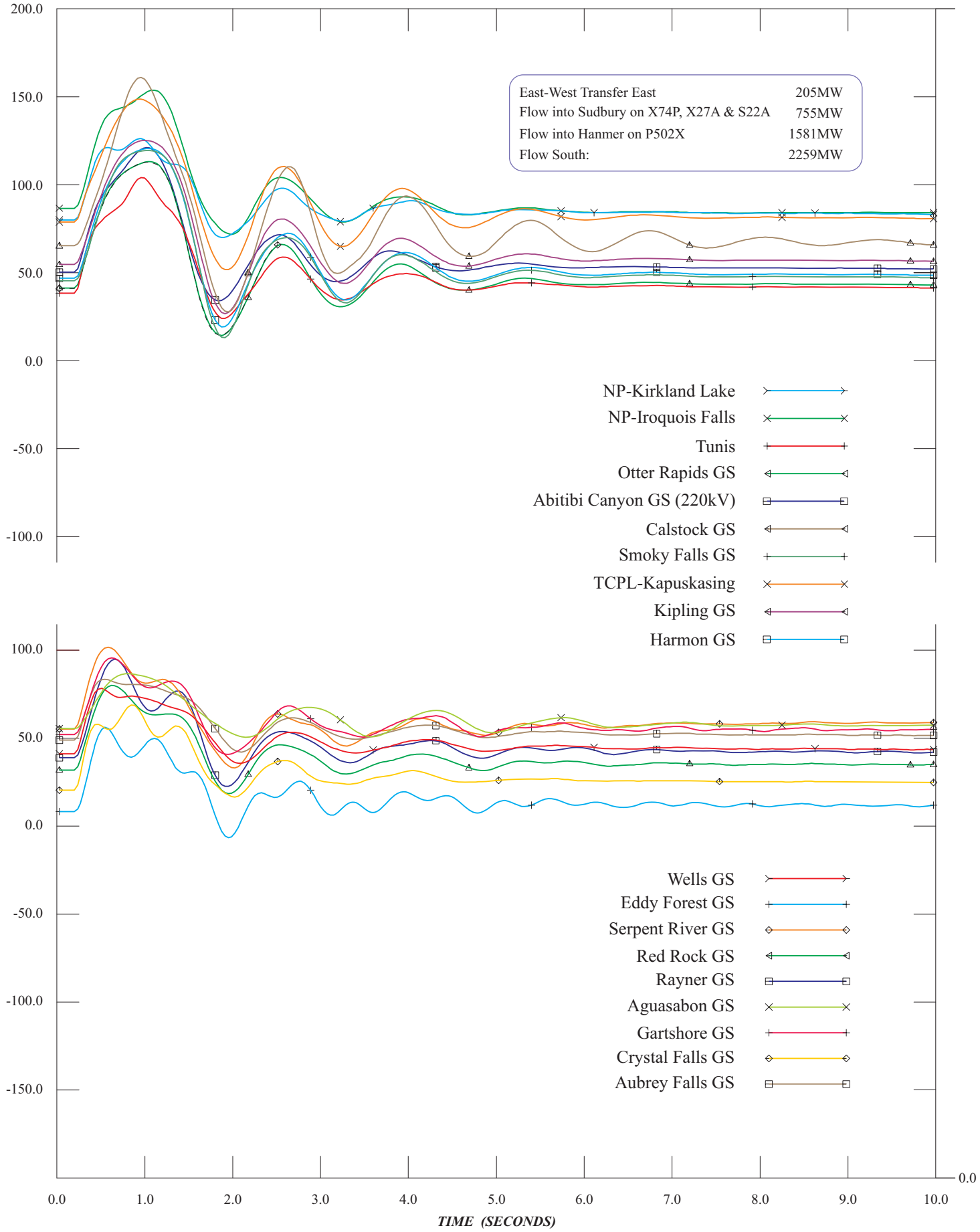
Algoma Voltage
Kirkland Lake Voltage
Kirkland Lake SVC MVArs
Porcupine Voltage
Porcupine SVC MVArs

Response of the SVCs, together with the associated system voltages, for a 3-phase fault on circuit X503E at Hanmer TS

With 50% comp. of Hanmer x Essa circuits + SVCs at Porcupine & Kirkland Lake

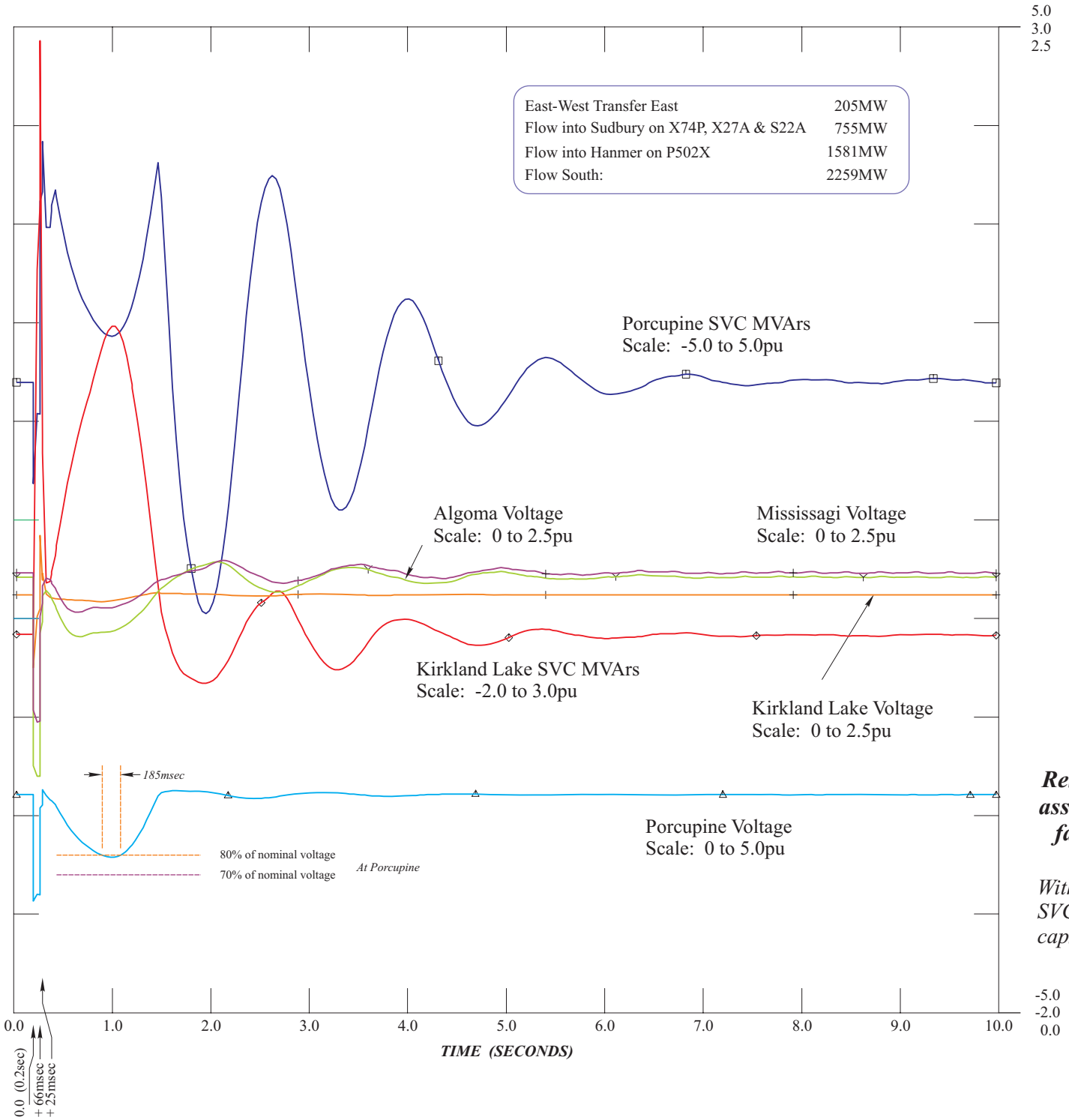
DIAGRAM 5

13th August 2007



Generator Rotor Angle Responses to a 3-Phase fault on circuit D501P at Porcupine TS
With 50% comp. of Hanmer x Essa circuits + SVCs at Porcupine TS & Kirkland Lake TS + shunt capacitors at Hanmer TS, Porcupine TS & Essa TS

DIAGRAM 6
13th August 2007



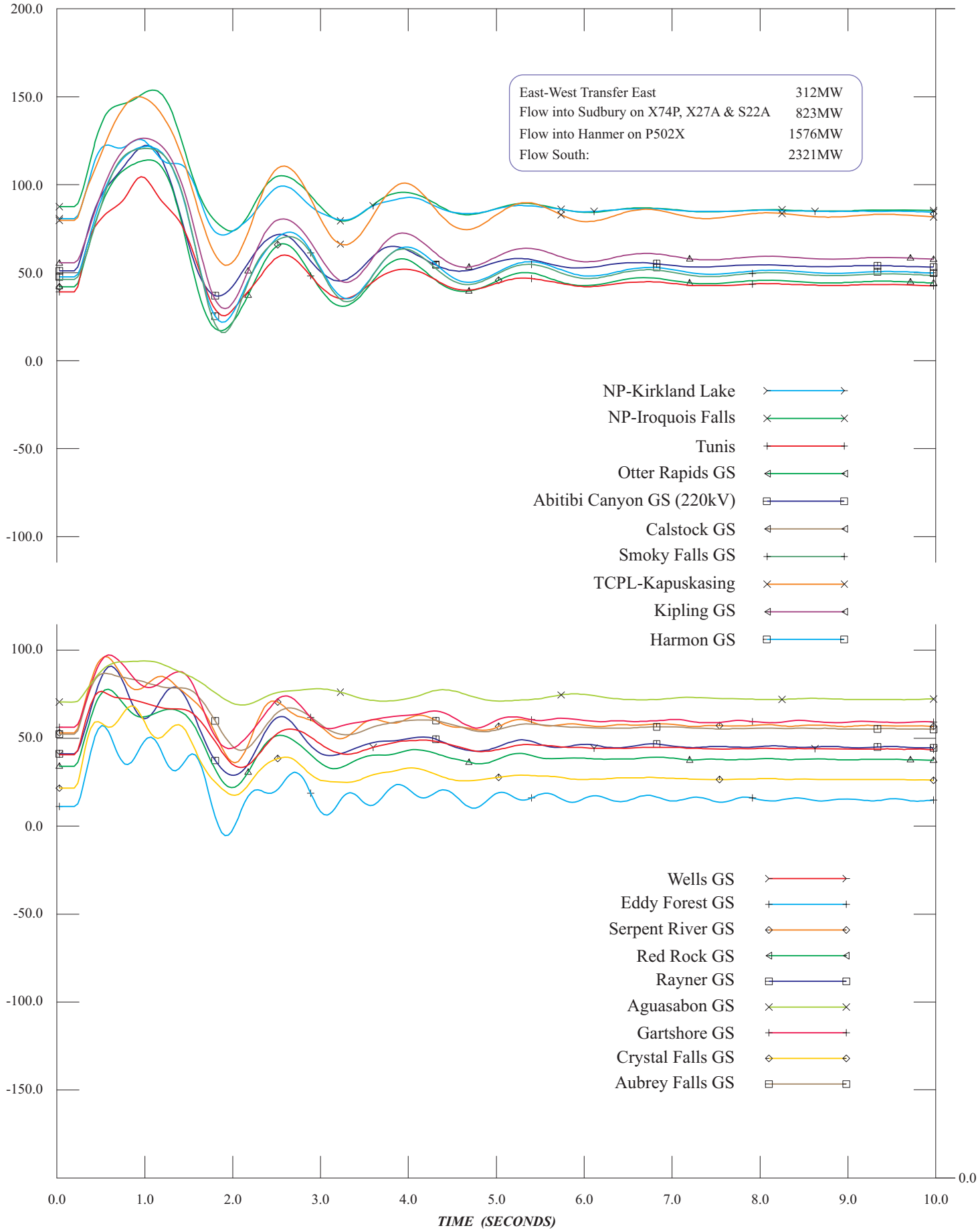
Algoma Voltage
Kirkland Lake Voltage
Kirkland Lake SVC MVArs
Porcupine Voltage
Porcupine SVC MVArs

Response of the SVCs, together with the associated system voltages, for a 3-phase fault on circuit X503E at Hanmer TS

With 50% comp. of Hanmer x Essa circuits + SVCs at Porcupine & Kirkland Lake + shunt caps at Hanmer, Porcupine & Essa

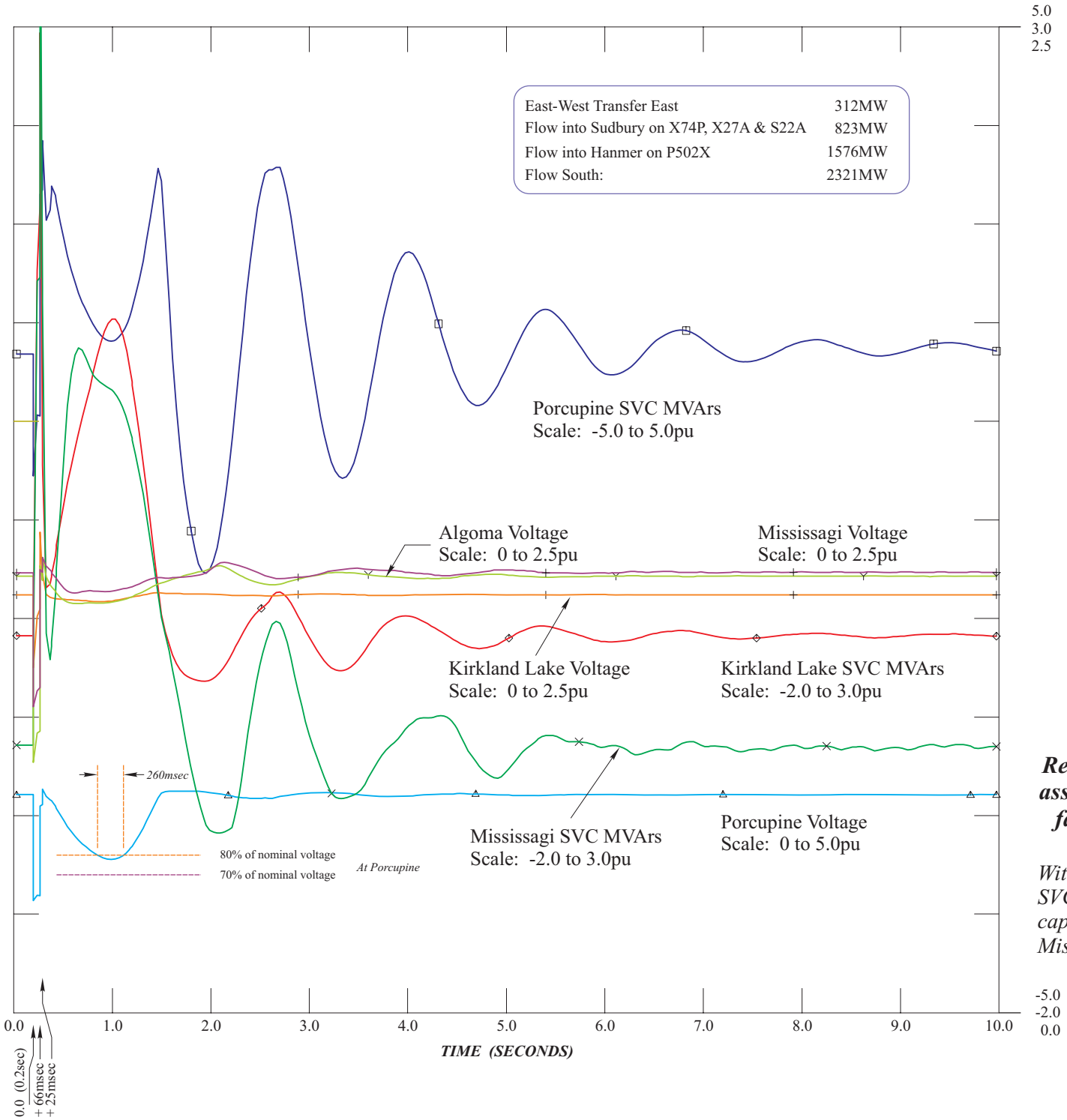
DIAGRAM 7

9th August 2007



Generator Rotor Angle Responses to a 3-Phase fault on circuit X503E at Hanmer TS
With 50% comp. of Hanmer x Essa circuits + SVCs at Porcupine & Kirkland Lake + shunt caps at Hanmer, Porcupine & Essa + SVC at Mississagi & caps at Mississagi & Algoma

DIAGRAM 8
13th August 2007



Algoma Voltage
Mississagi SVC MVArs
Kirkland Lake Voltage
Kirkland Lake SVC MVArs
Porcupine Voltage
Porcupine SVC MVArs

Response of the SVCs, together with the associated system voltages, for a 3-phase fault on circuit X503E at Hanmer TS

With 50% comp. of Hanmer x Essa circuits + SVCs at Porcupine & Kirkland Lake + shunt caps at Hanmer, Porcupine & Essa + SVC at Mississagi & caps at Mississagi & Algoma

DIAGRAM 9

13th August 2007